Conservation Laws, CP
Monte Carlo Particle ID's
Palm Products

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PDG Advisory Committee Meeting

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TESTS OF CONSERVATION LAWS

Revised by L. Wolfenstein and T.G. Trippe, May 2000.

In keeping with the current interest in tests of conservation laws, we collect together a Table of experimental limits on all weak and electromagnetic decays, mass differences, and moments, and on a few reactions, whose observation would violate conservation laws. The Table is given only in the full *Review of Particle Physics*, not in the Particle Physics Booklet. For the benefit of Booklet readers, we include the best limits from the Table in the following text. Limits in this text are for CL=90% unless otherwise specified. The Table is in two parts: "Discrete Space-Time Symmetries," *i.e.*, C, P, T, CP, and CPT; and "Number Conservation Laws," *i.e.*, lepton, baryon, hadronic flavor, and charge conservation. The references for these data can be found in the the Particle Listings in the *Review*. A discussion of these tests follows.

CP VIOLATION OBSERVED

charge asymmetry in $K^0_{\ell 3}$ decays		
$\delta(\mu) = [\Gamma(\pi^- \mu^+ \nu_\mu) - \Gamma(\pi^+ \mu^- \overline{\nu}_\mu)]/\text{sum}$		$(0.304 \pm 0.025)\%$
$\delta(e) = [\Gamma(\pi^- e^+ \nu_e) - \Gamma(\pi^+ e^- \overline{\nu}_e)]/\text{sum}$		$(0.333 \pm 0.014)\%$
parameters for $K^0_L \to 2\pi$ decay		
$\lvert\eta_{00}\rvert = \lvert A(K^0_L \to 2\pi^0) / A(K^0_S \to 2\pi^0)\rvert$		$(2.262 \pm 0.017) \times 10^{-3}$
$\lvert\eta_{+-}\rvert = \lvert A(K^0_L \to \pi^+ \pi^-) / A(K^0_S \to \pi^+ \pi^-)\rvert$		$(2.276 \pm 0.017) \times 10^{-3}$
$\epsilon'/\epsilon \approx \text{Re}(\epsilon'/\epsilon) = (1 - \lvert\eta_{00}/\eta_{+-}\rvert)/3$	[e]	$(2.1 \pm 0.5) \times 10^{-3}$ (S = 1.6)
ϕ_{+-}, phase of η_{+-}		$(43.3 \pm 0.5)^\circ$
ϕ_{00}, phase of η_{00}		$(43.2 \pm 1.0)^\circ$
CP asymmetry A in $K^0_L \to \pi^+ \pi^- e^+ e^-$		$(13.6 \pm 2.8)\%$
parameters for $K^0_L \to \pi^+ \pi^- \gamma$ decay		
$\lvert\eta_{+-\gamma}\rvert = \lvert A(K^0_L \to \pi^+ \pi^- \gamma, CP \text{ violating})/A(K^0_S \to \pi^+ \pi^- \gamma)\rvert$		$(2.35 \pm 0.07) \times 10^{-3}$
$\phi_{+-\gamma} =$ phase of $\eta_{+-\gamma}$		$(44 \pm 4)^\circ$
$\Gamma(K^0_L \to \pi^+ \pi^-)/\Gamma_{\text{total}}$		$(2.056 \pm 0.033) \times 10^{-3}$
$\Gamma(K^0_L \to \pi^0 \pi^0)/\Gamma_{\text{total}}$		$(9.27 \pm 0.19) \times 10^{-4}$

12. *CP* VIOLATION

Revised April 2000 by L. Wolfenstein (Carnegie-Mellon Univ.).

The symmetries C (particle-antiparticle interchange) and P (space inversion) hold for strong and electromagnetic interactions. After the discovery of large C and P violation in the weak interactions, it appeared that the product CP was a good symmetry. In 1964 CP violation was observed in K^0 decays at a level given by the parameter $\epsilon \approx 2.3 \times 10^{-3}$. Larger CP-violation effects are anticipated in B^0 decays.

12.1. *CP* violation in Kaon decay

From the experimental measurements, one finds

$$\epsilon = (2.271 \pm 0.017) \times 10^{-3} \,, \tag{12.8a}$$

$$\mathrm{Re}(\epsilon'/\epsilon) \approx \epsilon'/\epsilon = (2.1 \pm 0.5) \times 10^{-3} \,, \tag{12.8b}$$

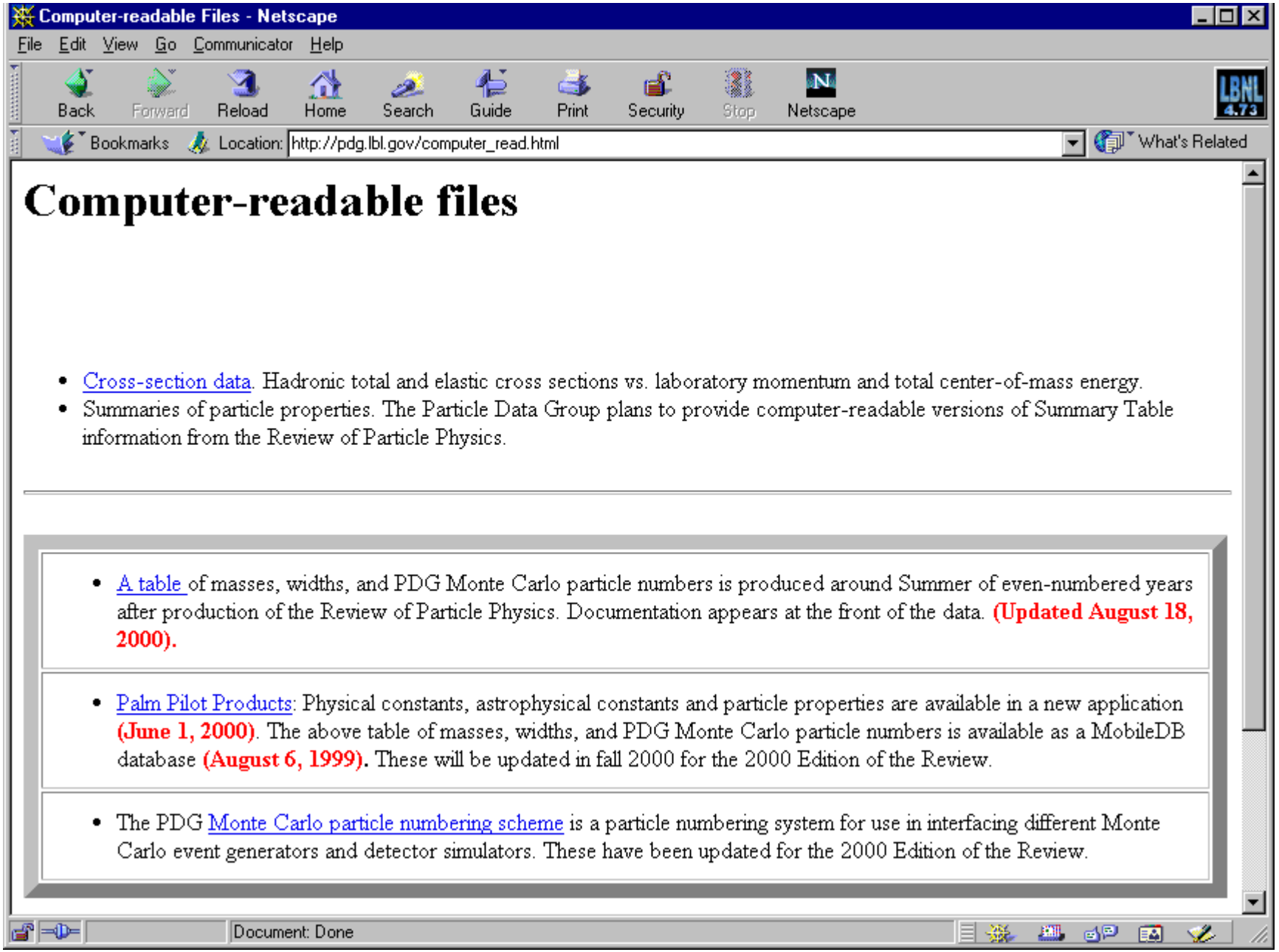
$$\phi_{+-} = 43.5 \pm 0.5^\circ \,, \tag{12.8c}$$

$$\phi_{00} - \phi_{+-} = -0.1 \pm 0.8 \,, \tag{12.8d}$$

$$\delta = (3.33 \pm 0.14) \times 10^{-3} \,. \tag{12.8e}$$

12.2. *CP* violation in *B* decay

For 2002 edition, maybe add B CP results (or cross-ref to CKM).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What's Related
Computer-readable files
Cross-section data. Hadronic total and elastic cross sections vs. laboratory momentum and total center-of-mass energy.
Summaries of particle properties. The Particle Data Group plans to provide computer-readable versions of Summary Table information from the Review of Particle Physics.
A table of masses, widths, and PDG Monte Carlo particle numbers is produced around Summer of even-numbered years after production of the Review of Particle Physics. Documentation appears at the front of the data. (Updated August 18, 2000).
Palm Pilot Products: Physical constants, astrophysical constants and particle properties are available in a new application (June 1, 2000). The above table of masses, widths, and PDG Monte Carlo particle numbers is available as a MobileDB database (August 6, 1999). These will be updated in fall 2000 for the 2000 Edition of the Review.
The PDG Monte Carlo particle numbering scheme is a particle numbering system for use in interfacing different Monte Carlo event generators and detector simulators. These have been updated for the 2000 Edition of the Review.
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30. MONTE CARLO PARTICLE NUMBERING SCHEME

Revised April 2000 by L. Garren (Fermilab), I.G. Knowles (Edinburgh U.), T. Sjöstrand (Lund U.), and T. Trippe (LBNL).

The Monte Carlo particle numbering scheme presented here is intended to facilitate interfacing between event generators, detector simulators, and analysis packages used in particle physics. The numbering scheme was introduced in 1988 [1] and a revised version [2,3] was adopted in 1998 in order to allow systematic inclusion of quark model states which are as yet undiscovered and hypothetical particles such as SUSY particles. The numbering scheme is used in several event generators, *e.g.* HERWIG and PYTHIA/JETSET, and in the **/HEPEVT/** [4] standard interface.

The general form is a 7–digit number:

$$\pm n\ n_r\, n_L\, n_{q_1}\, n_{q_2}\, n_{q_3}\, n_J\ .$$

This encodes information about the particle's spin, flavor content, and internal quantum numbers. The details are as follows:

1. Particles are given positive numbers, antiparticles negative numbers. The PDG convention for mesons is used, so that K^+ and B^+ are particles.
2. Quarks and leptons are numbered consecutively starting from 1 and 11 respectively; to do this they are first ordered by family and within families by weak isospin.
3. In composite quark systems (diquarks, mesons, and baryons) $n_{q_{1-3}}$ are quark numbers used to specify the quark content, while the rightmost digit $n_J = 2J + 1$ gives the system's spin (except for the K^0_S and K^0_L). The scheme does not cover particles of spin $J > 4$.

LIGHT $I = 1$ MESONS	
π^0	111
π^+	211
$a_0(980)^0$	9000111
$a_0(980)^+$	9000211
$\pi(1300)^0$	100111
$\pi(1300)^+$	100211
$a_0(1450)^0$	10111
$a_0(1450)^+$	10211
$\pi(1800)^0$	200111
$\pi(1800)^+$	200211
$\rho(770)^0$	113
$\rho(770)^+$	213
$b_1(1235)^0$	10113
$b_1(1235)^+$	10213
$a_1(1260)^0$	20113
$a_1(1260)^+$	20213
$\boldsymbol{\pi_1(1400)^0}$	9000113*
$\boldsymbol{\pi_1(1400)^+}$	9000213*
$\rho(1450)^0$	100113
$\rho(1450)^+$	100213
$\boldsymbol{\pi_1(1600)^0}$	**9010113***
$\boldsymbol{\pi_1(1600)^+}$	**9010213***
$\boldsymbol{a_1(1640)^0}$	**9020113***
$\boldsymbol{a_1(1640)^+}$	**9020213***
$\rho(1700)^0$	30113
$\rho(1700)^+$	30213
$\rho(2150)^0$	**9030113***
$\rho(2150)^+$	**9030213***

LIGHT $I = 0$ MESONS ($u\bar{u}$, $d\bar{d}$, and $s\bar{s}$ Admixtures)	
η	221
$\eta'(958)$	331
$f_0(400–1200)$	9000221
$f_0(980)$	9010221
$\eta(1295)$	100221
$f_0(1370)$	10221
$\eta(1440)$	100331
$f_0(1500)$	9020221
$\boldsymbol{f_0(1710)}$	**10331***
$\eta(1760)$	200221
$f_0(2020)$	**9030221***
$f_0(2060)$	**9040221***
$f_0(2200)$	**9050221***
$\eta(2225)$	**9060221***
$\omega(782)$	223
$\phi(1020)$	333
$h_1(1170)$	10223
$f_1(1285)$	20223
$h_1(1380)$	10333
$f_1(1420)$	20333
$\omega(1420)$	100223
$f_1(1510)$	9000223
$\boldsymbol{\omega(1650)}$	30223*
$\phi(1680)$	100333
$f_2(1270)$	225
$f_2(1430)$	9000225
$f_2'(1525)$	335

STRANGE MESONS	
K_L^0	130
K_S^0	310
K^0	311
K^+	321
$K_0^*(1430)^0$	10311
$K_0^*(1430)^+$	10321
$K(1460)^0$	100311
$K(1460)^+$	100321
$K(1830)^0$	200311
$K(1830)^+$	200321
$K_0^*(1950)^0$	9000311
$K_0^*(1950)^+$	9000321
$K^*(892)^0$	313
$K^*(892)^+$	323
$K_1(1270)^0$	10313
$K_1(1270)^+$	10323
$K_1(1400)^0$	20313
$K_1(1400)^+$	20323
$K^*(1410)^0$	100313
$K^*(1410)^+$	100323
$K_1(1650)^0$	9000313
$K_1(1650)^+$	9000323
$K^*(1680)^0$	30313
$K^*(1680)^+$	30323
$K_2^*(1430)^0$	315
$K_2^*(1430)^+$	325
$K_2(1580)^0$	9000315

*	Particle ID(s)		Value (GeV)	Errors (GeV)	Name	Charges
M	22		0.E+00	+0.0E+00 -0.0E+00	gamma	0
W	22		0.E+00	+0.0E+00 -0.0E+00	gamma	0
M	24		8.042E+01	+6.0E-02 -6.0E-02	W	+
W	24		2.12E+00	+5.0E-02 -5.0E-02	W	+
M	23		9.11882E+01	+2.2E-03 -2.2E-03	Z	0
W	23		2.4952E+00	+2.6E-03 -2.6E-03	Z	0
W	11		0.E+00	+0.0E+00 -0.0E+00	e	-
M	11		5.10998902E-04	+2.1E-11 -2.1E-11	e	-
M	13		1.05658357E-01	+5.0E-09 -5.0E-09	mu	-
W	13		2.99591E-19	+5.0E-24 -5.0E-24	mu	-
M	15		1.77703E+00	+3.0E-04 -2.6E-04	tau	-
W	15		2.265E-12	+9.0E-15 -9.0E-15	tau	-
M	12		0.E+00	+0.0E+00 -0.0E+00	nu(e)	0
W	12		0.E+00	+0.0E+00 -0.0E+00	nu(e)	0
M	14		0.E+00	+0.0E+00 -0.0E+00	nu(mu)	0
W	14		0.E+00	+0.0E+00 -0.0E+00	nu(mu)	0
M	16		0.E+00	+0.0E+00 -0.0E+00	nu(tau)	0
W	16		0.E+00	+0.0E+00 -0.0E+00	nu(tau)	0
M	6		1.74E+02	+5.0E+00 -5.0E+00	t	0
M	211		1.3957018E-01	+3.5E-07 -3.5E-07	pi	+
W	211		2.5284E-17	+5.0E-21 -5.0E-21	pi	+
M	111		1.349766E-01	+6.0E-07 -6.0E-07	pi	0
W	111		7.8E-09	+6.0E-10 -5.0E-10	pi	0
M	221		5.4730E-01	+1.2E-04 -1.2E-04	eta	0
W	221		1.18E-06	+1.1E-07 -1.1E-07	eta	0
M	113	213	7.693E-01	+8.0E-04 -8.0E-04	rho(770)	0,+
W	113	213	1.502E-01	+8.0E-04 -8.0E-04	rho(770)	0,+
M	223		7.8257E-01	+1.2E-04 -1.2E-04	omega(782)	0
W	223		8.44E-03	+9.0E-05 -9.0E-05	omega(782)	0
M	331		9.5778E-01	+1.4E-04 -1.4E-04	eta'(958)	0
W	331		2.02E-04	+1.6E-05 -1.6E-05	eta'(958)	0
M	9010221		9.80E-01	+1.0E-02 -1.0E-02	f(0)(980)	0
M	9000111	9000211	9.848E-01	+1.4E-03 -1.4E-03	a(0)(980)	0,+
M	333		1.019417E+00	+1.4E-05 -1.4E-05	phi(1020)	0
W	333		4.458E-03	+3.2E-05 -3.2E-05	phi(1020)	0
M	10223		1.170E+00	+2.0E-02 -2.0E-02	h(1)(1170)	0
W	10223		3.6E-01	+4.0E-02 -4.0E-02	h(1)(1170)	0
M	10113	10213	1.2295E+00	+3.2E-03 -3.2E-03	b(1)(1235)	0,+
W	10113	10213	1.42E-01	+9.0E-03 -9.0E-03	b(1)(1235)	0,+

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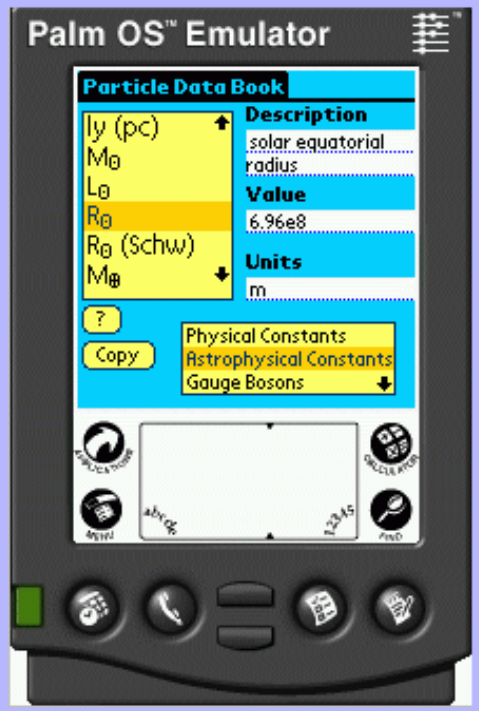
Palm products from the Particle Data Group

The Particle Data Group is porting some of our databases and information to the Palm computing environment. This is just a beginning. We also give other physics related links below. Keep those comments and suggestions flowing to PDG consultant John Krane (jkrane@fnal.gov) or PDG contact Tom Trippe (trippe@lbl.gov).

NEW Particle Data Book (Palm Implementation)

Doug Lowder has contributed a Palm implementation of the Particle Physics Booklet containing tables of physical and astrophysical constants, and particle properties. Numerical values can copied/pasted into Palm calculators. See his Particle Data Book page for more information and download. This is a stand-alone application, i.e. no other application software is needed to use it.



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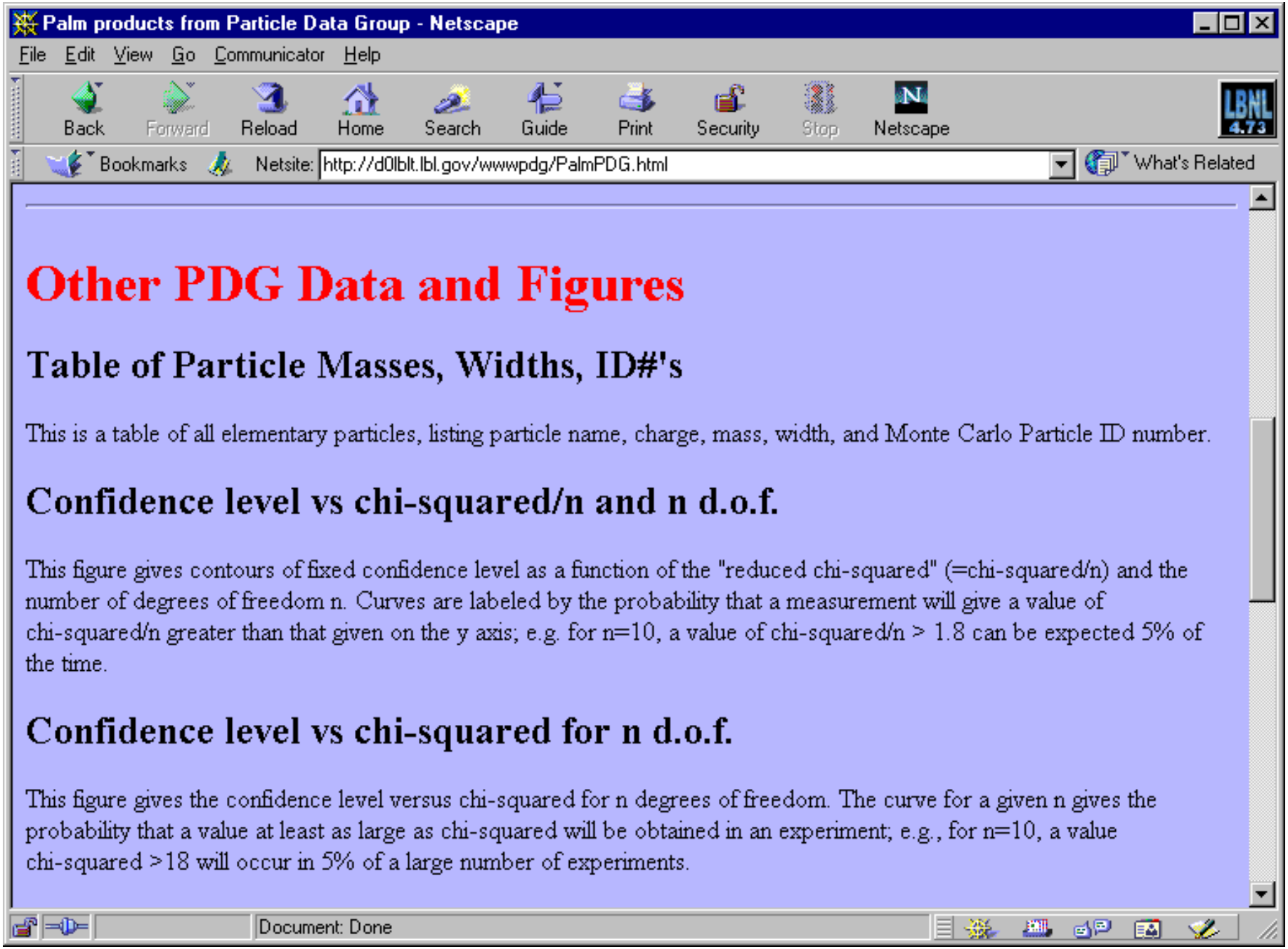
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Table of Particle Masses, Widths, ID#'s
This is a table of all elementary particles, listing particle name, charge, mass, width, and Monte Carlo Particle ID number.
Confidence level vs chi-squared/n and n d.o.f.
This figure gives contours of fixed confidence level as a function of the "reduced chi-squared" (=chi-squared/n) and the number of degrees of freedom n. Curves are labeled by the probability that a measurement will give a value of chi-squared/n greater than that given on the y axis; e.g. for n=10, a value of chi-squared/n > 1.8 can be expected 5% of the time.
Confidence level vs chi-squared for n d.o.f.
This figure gives the confidence level versus chi-squared for n degrees of freedom. The curve for a given n gives the probability that a value at least as large as chi-squared will be obtained in an experiment; e.g., for n=10, a value chi-squared >18 will occur in 5% of a large number of experiments.
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Future

- Palm Products
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  - Full Particle Properties, including decay modes
  - Better viewer for plots, including fixed axes, readout
  - Booklet texts?
- Other Devices and Formats
  - General (comma delimited) formats for Excel, etc.
  - Volunteers to convert to specific Palm, other device apps.